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Computer Modeling of Dust and Forces for Longwall Mining Systems

By B. D. Hanson and W. W. Roepke

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute	lb/ft^3	pound per cubic foot
deg	degree	lb/in^2	pound per square inch
ft/min	foot per minute	pct	percent
ft•lb	foot pound	psi	pound (force) per square inch
hp	horsepower	rpm	revolution per minute
in	inch	yr	year
lb	pound		

COMPUTER MODELING OF DUST AND FORCES FOR LONGWALL MINING SYSTEMS

By B. D. Hanson[1] and W. W. Roepke[2]

ABSTRACT

An interactive computer program has been developed by the Bureau of Mines which enables the user to identify the effect of cutting system changes on relative dust generation for longwall shearer drums. The program simultaneously evaluates machine and coal seam parameters, and those parameters which the user can control. The user can change one or more of these parameters at a time to determine their effect on relative dust generation, cutting forces, and/or cost. The program is written in the BASIC programming language. A complete program listing is included along with user instructions and sample outputs. This program is a more comprehensive version of the relative dustiness index (REDI) program described in Bureau Report of Investigations 8979.

INTRODUCTION

Since the enactment of the Federal Coal Mine Health and Safety Act of 1969, the Bureau of Mines has conducted an extensive research program on the control and reduction of respirable coal dust. Over the past 15 yr, research has been conducted in small-scale laboratory tests, in intermediate-sized prototype tests, and in full-scale in-mine demonstrations. The main objective of the work at the Bureau's Twin Cities (MN) Research Center has been the determination of the effect of controllable cutting system parameters on respirable dust generation. These controllable parameters include depth of cut, bit spacing, bit geometry, and operating conditions.

The body of data collected during this research provides a broad base of knowledge on the coal cutting phenomenon. The results are available to the industry in the form of a multitude of Bureau publications. There is so much information in so many places that individuals interested in reducing respirable dust generation at a specific mining operation will have difficulty finding their way through the available data to extract the specific information they need. The advent of the microcomputer and its universal availability provides a means of alleviating this problem.

This report presents a cutting system model (CSM) that incorporates the research results on the effects of various cutting system parameters on the generation of respirable coal dust. The CSM provides the user with a means to evaluate, on a relative basis, the effect of cutting system changes without the time or expense of actual equipment modification. The CSM is an advanced version of REDI *(1)*.[3] This new version incorporates preliminary models of multiple bit interaction and bit wear effects.

The CSM mathematically evaluates the effects of cutting system changes on primary respirable dust generation. A longwall respirable dust simulator developed by Haney *(2)* at the Mine Safety and Health Administration (MSHA) correlates the effects of secondary dust sources and primary dust generated by cutting action of the drum. The MSHA model requires personal dust exposure measurements and dust source measurements collected at the face to determine the contribution of each dust source to the worker's exposure. The MSHA program provides a qualitative list of recommended options to aid in correcting any compliance problems.

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[1]Physical scientist.
[2]Supervisory physical scientist.
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[3]Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

PROGRAM DESCRIPTION

The CSM program was developed to analyze the relative dust generated by a double-drum ranging arm shearer cutting in a coal seam containing rock band or middle man. Simpler situations, such as a single drum shearer, may also be analyzed. The program is menu driven, allowing the user to make parametric changes with a minimum of steps. It is written in BASIC and will run on an IBM[4] personal computer (PC), or equivalent. The menus through which the program operates allow the user to change parameter values, calculate dust values, save modified data files, obtain printer copies of summary reports, lists of modifications, and a listing of the entire data file. Also, two "Help" menus provide online assistance to the user. The program performs the analysis using either a fixed number of bits, or will vary the number of bits based on the cut depth and a space-depth ratio specified by the user. A program listing is given in appendix A. The parameters used are defined in appendix B.

The logical flow of the program is shown in figure 1. An average cut depth will be calculated based on either a user specified advance rate, or, if none is supplied, the computer will calculate the advance rate from the maximum volume of cut coal that the drum can hold. Maximum volume is defined as

$$V_o = (D_o^2 - D_i^2)W(\pi/4) - (V_l V_h V_t V_n),$$

where D_o = drum diameter,

D_i = inner drum diameter,

W = web width,

V_l = vane length,

V_h = vane height,

V_t = vane thickness,

and V_n = number of starts (vanes).

If the user has selected the fixed space-depth ratio mode for the analysis, the number of bits is calculated. The space to depth ratio (S-D) may be set to any value the operator chooses. The average cut depth will them be computed for each vertical strata (coal, rock, coal) through which the drum is cutting (fig. 2). This average cut depth is calculated based on the analysis of rotary cutting performed by Roepke *(3)*. The equation used is

$$\text{average depth} = \int_{W_1}^{W_2} \frac{D(W)\,dW}{(W_2 - W_1)},$$

where W_1 = angle at entry,

W_2 = angle at exit,

$D(W) = R + A\cos(W) - (R^2 - A^2\sin^2(W))^{1/2}$ unless $D(W) > D_{max}$, in which case $D(W) = D_{max}$,

R = drum radius,

A = advance per revolution,

D_{max} = maximum cut depth due to bit interaction,

and W = rotation angle about drum center.

Once the average cut depth is calculated, the cutting and normal forces will be computed. Both the cutting and normal forces have been shown to be linear functions of depth *(3-4)*. The force equations are defined by a slope and intercept, which can be obtained from either laboratory cutting tests or from in situ measurements with the Bureau's in-seam tester *(5)*. The effect of bit wear is incorporated by the application of multipliers to both the cutting and normal forces. For new bits (e.g., wear equal to 0 pct), the multiplier is 1. A wear effect with up to three different stages of wear can be used by the program. The wear effect values used in appendix C (parameters 39 to 60) are taken from laboratory wear research results *(4)*.

The required drum torque and advancing thrust are then calculated from the cutting and normal forces, drum revolution per minute, drum diameter, and number of bits. If either the torque or thrust exceeds that which is available, the advance rate is reduced to 95 pct of the current value and the calculation procedure is repeated. This iterative process is continued until both the required torque and thrust are less than available. Airborne dust, production, and cost values are calculated for a summary report. The program then returns the user to the main menu.

[4]Reference to specific products does not imply endorsement by the Bureau of Mines.

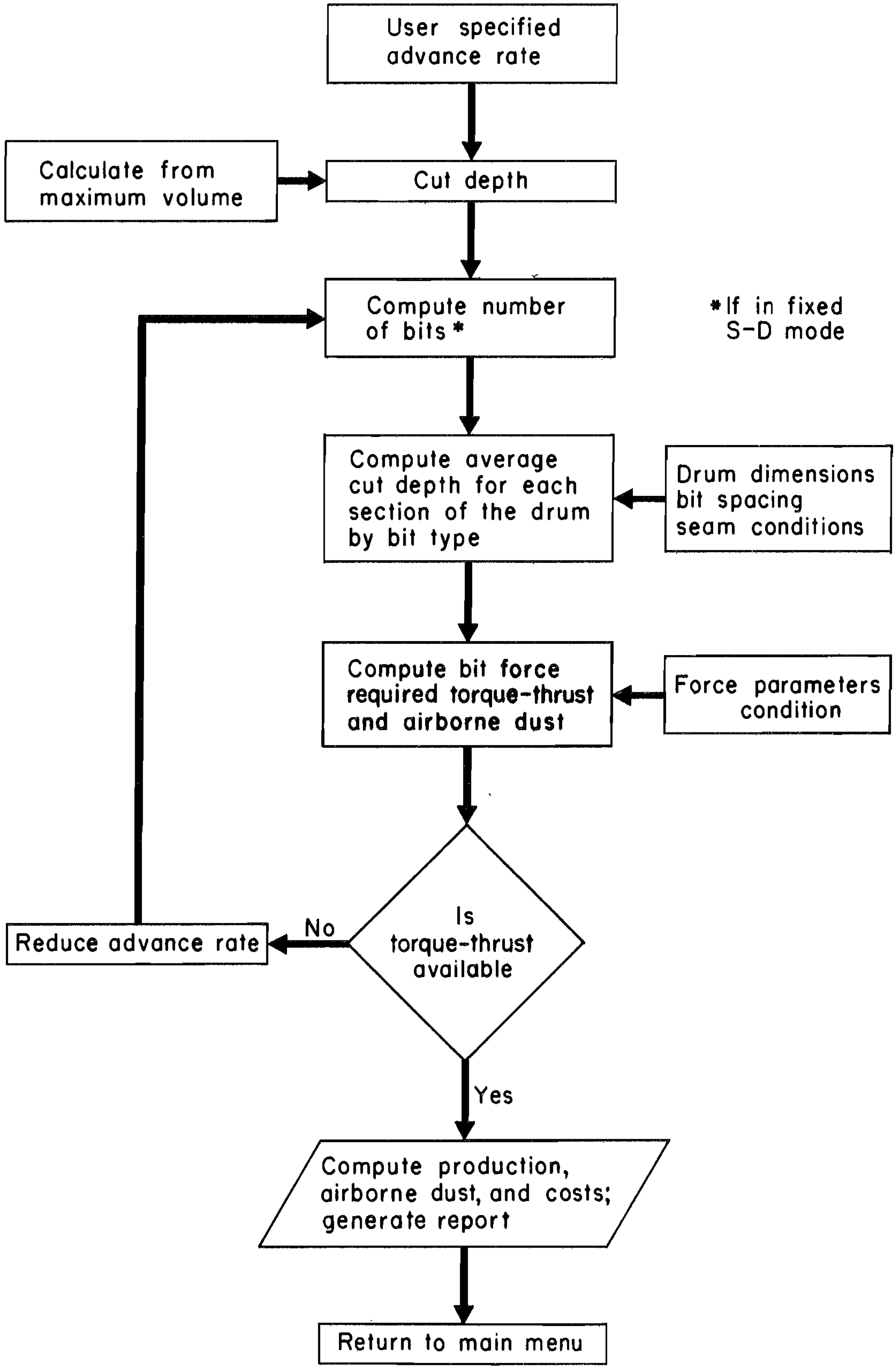

Figure 1.—Program flowchart.

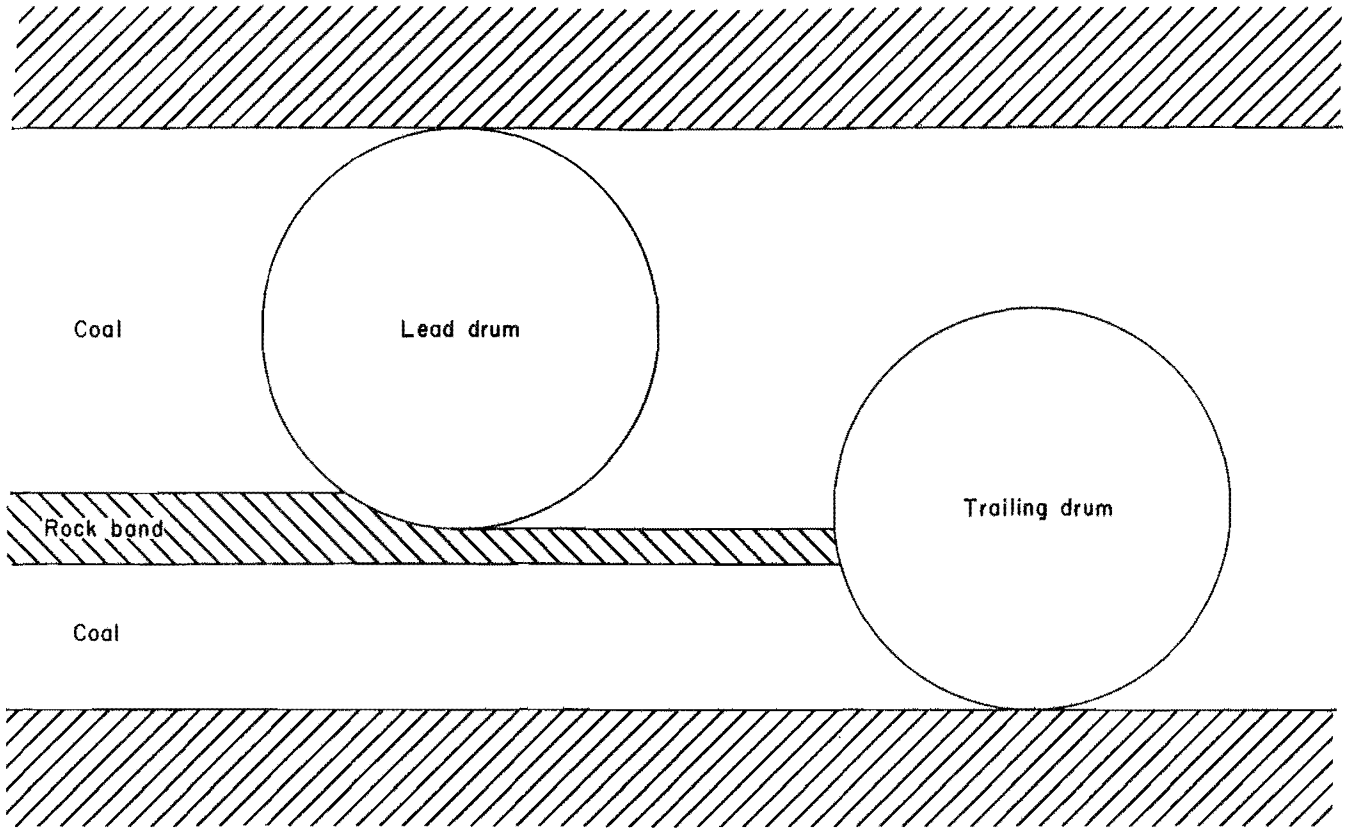

Figure 2.—Seam cross section.

PROGRAM OPERATION

The program is menu driven. The main menu, which controls all the program functions, is shown in figure 3. Selecting item 1 on this menu causes the program to recalculate the relative dust value using the procedures described in the previous section. Figure 4 shows an example of the summary report that is generated by the analysis. At this point the user is given the option of printing a hard copy of the report. The user will be returned to the main menu regardless of the choice made.

Changes in parameter values are accomplished by using item 2 on the main menu, which gives the user access to the parameter modification menu (fig. 5). The parameters used by the program are divided into the five categories listed in figure 5. Appendix B gives a list of parameter definitions and identifies the category in which the parameter appears. Figure 6 demonstrates how a parameter value (in this case, drum revolutions) would be changed. Item 3 on the main menu allows the user to specify the advance rate either in foot per minute or ton per shift. If an advance rate is not specified the program will automatically calculate the advance rate based on the maximum volume of coal that the drum can transport without excessive secondary dust generation caused by crushing and regrinding of the cut coal. If the user sets the advance rate higher than this maximum, the program will perform all the necessary calculations to determine forces, cost, and production. However, no relative dust value will be printed. Instead, the program will print a statement indicating that the drum is overloaded and causing excessive secondary dust generation. Selecting item 4 allows the analysis to be done using any fixed space-depth ratio set by the user. The number of bits will be determined from the calculated average cut depth and S-D ratio. If option 4 is not selected, the analysis will be performed using the number of bits specified in element 25 of the parameter list. Item 5 sets the wear condition of the bits. The value is entered as a percent of total bit life. Item 6 provides a data file utility that allows saving the current data file, inputting a new data file, or obtaining a hard copy of the entire data file. Item 7 provides online help messages to assist the user. Selecting this item causes another menu (fig. 6) to be printed. The first six items of the help index menu are identical to their counterparts on the main menu. Selecting the appropriate item from this menu will cause a help message covering the subject to be printed. The parameter modification menu also contains a help index, which covers the items in that menu.

Two aspects of the analysis are controlled by the parameter values. Setting the rock band top (data element 21) and the rock band bottom (data element 22) equal to

```
################################  MAIN MENU  ################################

1 - RECALCULATE RELATIVE DUST VALUE     2 - MODIFY SYSTEM PARAMETERS
3 - SPECIFY ADVANCE RATE                4 - SPECIFY SPACE/DEPTH RATIO
5 - CHANGE WEAR CONDITION               6 - DATA FILE UTILITY
7 - HELP INDEX                          8 - TERMINATE PROGRAM

        ENTER THE NUMBER FOR THE ACTION YOU WISH TO DO NEXT ? 2
```

Figure 3.—Main menu.

```
THE DRUM ADVANCE IS NOT LIMITED           THE BITS ARE  0  PERCENT WORN

MAX. CUT DEPTH, VANE BIT (IN)     1.76    MAX. CUT DEPTH, GAGE BIT (IN)     1.47
LINE BIT SPACING (IN)             4.93    NUMBER OF GAGE LINES              5.00
BITS PER VANE                     7.00    NUMBER OF GAGE BITS PER LINE      3.60
BIT SPACE TO DEPTH RATIO          2.79

AVAILABLE ADVANCING THRUST        6000    AVAILABLE CUTTER TORQUE          50000
LEAD DRUM ADVANCING THRUST        4606    LEAD DRUM CUTTER TORQUE          15863
TRAILING DRUM ADV. THRUST         2685    TRAILING DRUM CUTTER TORQUE       9167

ADVANCE (FT/MIN)                 15.00    TONS PER SHIFT                 2550.24

COST/TON - BITS AND POWER         0.25    COST/SHIFT - BITS AND POWER     649.19

VANE CONTRIBUTION (PCT)          57.45    GAGE CONTRIBUTION (PCT)          42.55

  ***********************************************************************
  * FULL SHIFT RELATIVE DUST -     492.61 PER TON      3.42 PER CU. M.  *
  ***********************************************************************
```

Figure 4.—Sample summary report.

```
#######################  PARAMETER MODIFICATION MENU  #####################

1 - MACHINE PARAMETERS                  2 - SEAM PARAMETERS
3 - OPERATOR CONTROLLABLE PARAMETERS    4 - BIT NORMAL FORCE PARAMETERS
5 - BIT CUTTING FORCE PARAMETERS        6 - HELP INDEX
7 - RETURN TO MAIN MENU

     ENTER THE NUMBER FOR THE PARAMETER GROUP YOU WISH TO MODIFY ? 1
```

Figure 5.—Parameter modification menu.

the same value eliminates the rock band from the calculations. Secondly, if the mining height (data element 24) and the drum diameter are the same, the program assumes there is only a single drum cutting.

The program has a built-in limit on the number of bits per vane. This limit is calculated from the bit block and drum dimensions. If the number of bit blocks reaches the physical limit for the space available, the program will continue the calculations fixing the number of bits at this maximum. Should the program reach the maximum number of bits, a message stating this fact will appear on the screen.

```
 1  - DRUM DIAMETER (IN)                        66
 2  - TOP VANE DIAMETER (IN)                    60
 3  - INNER DRUM DIAMETER (IN)                  34
 4  - WEB WIDTH (IN)                            38.5
 5  - VANE WIDTH (IN)                           34.5
 6  - VANE THICKNESS (IN)                       2
 7  - VANE HEIGHT (IN)                          12.99
 8  - DRUM VANE WRAP (DEG)                      220
 9  - AVAILABLE ADVANCING THRUST (LB)           6000
 10  - AVAILABLE CUTTER TORQUE (FT-LB)          50000
 11  - NUMBER OF STARTS                         3
 12  - NUMBER OF GAGE LINES                     5
 13  - DRUM REVOLUTIONS (RPM)                   34

ENTER THE NUMBER OF THE VARIABLE YOU WISH
TO CHANGE, USE ZERO(0) TO TERMINATE - ? 13
ENTER NEW DRUM REVOLUTIONS (RPM) - ? 45

ENTER THE NUMBER OF THE VARIABLE YOU WISH
TO CHANGE, USE ZERO(0) TO TERMINATE - ? 0

DO YOU WISH A HARD COPY OF THESE CHANGES (Y/N) ? Y
```

Figure 6.—Parameter change example.

PROGRAM USE

In using the CSM to analyze drum designs it is important to realize the user may not have access to values for all the parameters used by the program. A number of the variables in the program were included in anticipation of program expansion and/or development of broader data bases to more fully support the program. Table 1 specifies which data elements must be known to analyze relative dust; forces and drum torque requirements; bit and power costs and production; and to evaluate the effect of bit wear. Appendix C lists a data file used in development of the program which can be used for default values.

Data elements 9 and 10 (available advancing thrust and available cutting torque) are used by the program to limit the maximum advance of the shearer. In determining the proper values to use, advancing thrust should reflect only the thrust available to advance the drum into the face. The force necessary to move the machine should not be included in data element 9. Also, the value for available cutting torque should reflect not only the cutting motor torque, but also the shearer's ability to react that torque load. The cutting motors may have the capability to generate more torque than the shearer can successfully react, resulting in the shearer climbing the face. The value used for data element 10 should take this into consideration. The equipment manufacturer should have this information.

Since the program was developed as a relative dust indicator, the default values for the first and second dust parameters and grindability should be adequate for most applications. The four slope-intercept pairs (data elements 35-38 and 48-51) needed for normal and cutting forces can be obtained by using the Bureau's in-seam-tester (*5*) or from laboratory tests. Data elements 39-47 and 52-60 are used to determine normal and cutting force as a function of wear condition. Ongoing Bureau bit wear testing on a number of different bit types will provide data that can be used to determine these data elements.

Data element 30, dust suppression, is included to allow a measured value to be used if the operator wishes to make the program site specific. Normally, it need not be changed by a user.

The interaction between the parameters is complex and the effect of changing any single parameter is dependent on the values of the others. The two variables that have the major influence on dust generation are the depth of cut and the number of bits on the drum. Increasing the depth of cut and/or reducing the number of bits will reduce the dust generated by the drum. While the number of bits is limited by only the bit block dimensions, the depth of cut may be limited by any of several variables. The depth of cut is determined by the advance rate, the drum revolution per minute, and the number of starts.

TABLE 1. - Minimum data requirements

Element	Name	Relative dust	Force, drum torque	Cost or production	Bit wear effects
1	Drum diameter	x	x	x	x
2	Top vane diameter	x	x	x	x
3	Inner drum diameter	x	x	x	x
4	Web width	x	x	x	x
5	Vane width	x	x	x	x
6	Vane thickness	x	x	x	x
7	Vane height	x	x	x	x
8	Drum vane wrap	x	x	x	x
9	Available advancing thrust		x	x	x
10	Available cutting torque		x	x	x
11	Number of starts	x	x	x	x
12	Number of gauge lines	x	x	x	x
13	Drum revolutions	x	x	x	x
14	1st dust parameter	x			x
15	2nd dust parameter	x			x
16	Compressive strength[1]				
17	Grindability index	x			x
18	Swell factor	x	x	x	x
19	Density			x	x
20	Breakout angle		x	x	x
21	Rock band top	x	x	x	x
22	Rock band bottom	x	x	x	x
23	Percent silica in rock band			x	
24	Mining height	x	x	x	x
25	Bits per vane	x	x	x	x
26	Bit block length	x	x	x	x
27	Bit block width	x	x	x	x
28	Number of gauge bits	x	x	x	x
29	Airflow	x			
30	Dust suppression	x			
31	Production time per shift	x		x	x
32	Cost per bit			x	x
33	Cost per kilowatt-hour			x	x
34	Bit life			x	x
35	Normal force intercept		x	x	x
36	Normal force slope		x	x	x
37	Rock band normal force intercept		x	x	x
38	Rock band normal force slope		x	x	x
39	1st stage end point				x
40	1st stage intercept				x
41	1st stage slope				x
42	2d stage end point				x
43	2d stage intercept				x
44	2d stage slope				x
45	3d stage end point				x
46	3d stage intercept				x
47	3d stage slope				x
48	Cutting force intercept		x	x	x
49	Cutting force slope		x	x	x
50	Rock band cutting force intercept		x	x	x
51	Rock band cutting force slope		x	x	x
52	1st stage end point				x
53	1st stage intercept				x
54	1st stage slope				x
55	2d stage end point				x
56	2d stage intercept				x
57	2d stage slope				x
58	3d stage end point				x
59	3d stage intercept				x
60	3d stage slope				x

[1]Not used in current version of program.

The advance rate in turn may be limited by the volume of cut coal the drum can hold or by high cutting or normal forces. These high cutting and normal forces could result from the presence of a rock-band or by assuming highly worn bits. The total force on the drum is a function of the number of vane bits and gauge bits. The percent contribution of the vane and gauge bits to the dust make is given in the summary report (fig. 4) to aid the user in determining the best place from which to remove bits.

The dust values computed by the program are relative. A single value of 10.0, for example, has no meaning unless another number is generated by a change in some parameter(s). If the second number is lower than 10.0, then the change should result in lower dust generation and vice versa.

VERIFICATION

A comparison of relative dust values calculated by the CSM and in-mine results from a Bureau contract (*6*) was made. The drum specifications and operating conditions for the test drum are given in table 2. Table 3 shows the combinations of drum speed and bits per vane that were run, along with the average advance rate for each combination. The 7.5 bit per vane figure shown in these two tables occurs because as part of the test series every other bit on each vane was removed, leaving seven bits on one vane and eight on the other, thereby doubling the bit spacing on each vane. Since the CSM treats both vanes as being equal, 7.5 bits per vane was used. The values for inner drum diameter, vane thickness, and vane height were estimated since values were not given in reference 6. The value of 14 in for inner drum diameter was necessary to allow sufficient open volume in the drum to allow the 27.5 ft/min advance rate. This could have also been accomplished by specifying a lower swell factor and using a larger inner drum diameter. The results from the CSM analysis and the test results are shown in table 4 and figure 7. Both the test results and CSM analysis show an increase in dust generation as drum speed is increased and a drop in dust generation as the number of bits per vane was halved. The test result data show a higher rate of increase with drum speed than does the CSM analysis, while the drop in dust generation, due to removal of bits, was approximately the same order of magnitude.

Other reports on field tests were reviewed for use in evaluating the CSM. None of the field tests covered by these reports were conducted in a manner that allowed the results to be used to evaluate the CSM. The primary problem was that variables not modelled by the CSM, such as water spray systems, were simultaneously changed with the cutting system parameters. This effectively masks any changes in dust generation due to changes in the cutting system.

TABLE 2. - Parameter values for verification

Variable	Value
Diameter, in:	
Tip to tip	60
Top vane diameter	52
Inner drum diameter	14
Web width . . . in	30
Vane, in:	
Width	27
Thickness	1
Height	19
Wrap angle . . . deg	360
Number of—Starts	
Bits per vane	7.5, 15
Gauge lines	5
Gauge bits	18
Drum speed . . . rpm	35, 45, 55, 70

TABLE 3. - Test conditions

Drum speed, rpm	Bits per vane	Av advance rate, ft/min
35	15	27.3
45	15	27.5
55	15	19.8
	7.5	24.5
70	15	21.8
	7.5	23.0

TABLE 4. - Comparison of test results and CSM analysis

Drum speed, rpm	Bits per vane	Dust value Test	Dust value CSM
35	15	132	183
45	15	190	229
55	15	297	264
	7.5	179	191
70	15	378	330
	7.5	297	224

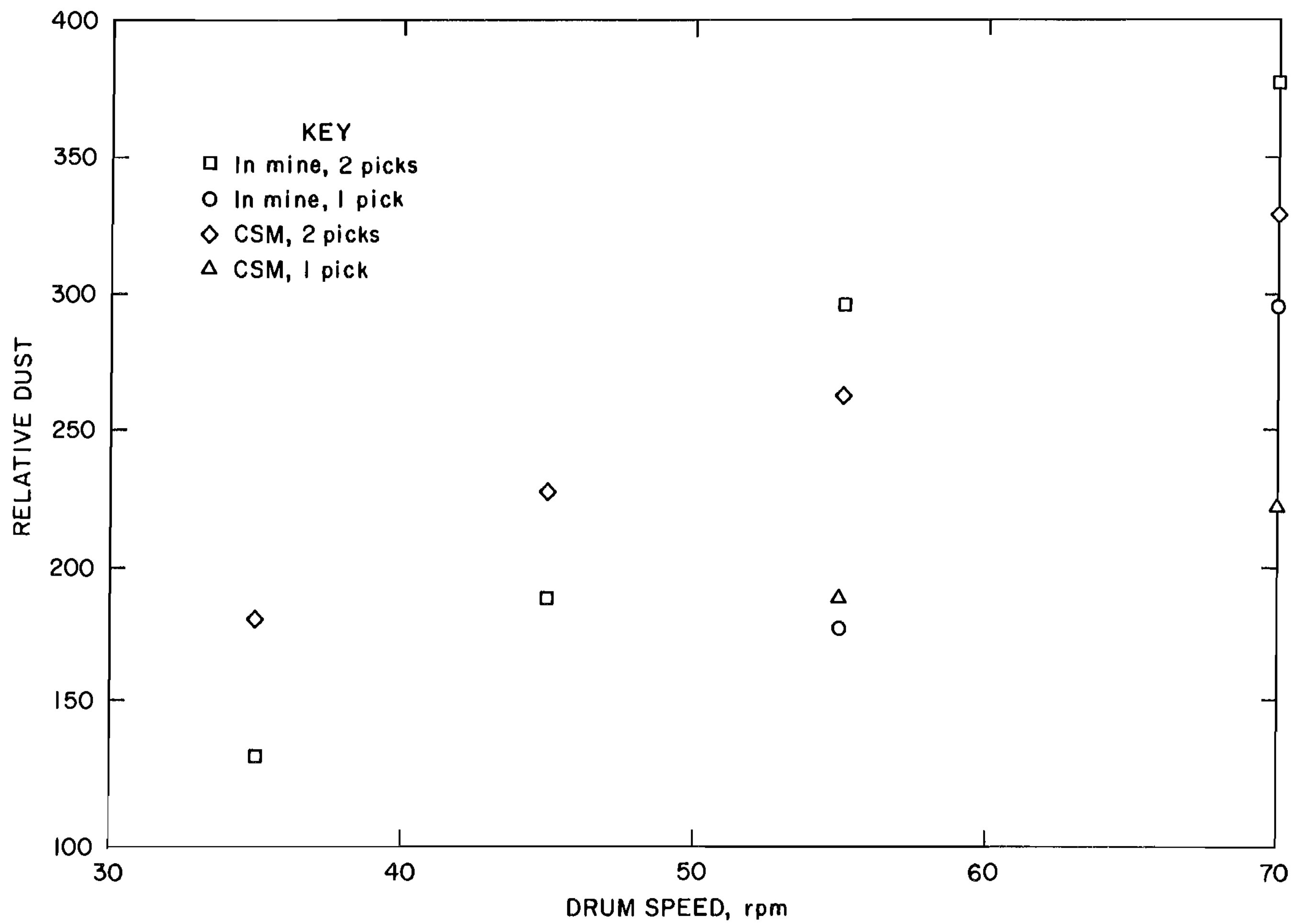

Figure 7.—Comparison of field and CSM results.

DISCUSSION

An interactive computer program has been developed which allows the user to evaluate, on a relative basis, the effect of cutting system changes on primary dust generation for double arm ranging shearers. The program is written in BASIC for use on IBM compatible microcomputers. The program is menu driven and allows the user to systematically vary cutting system parameters either individually or collectively to determine their effect on dust generation.

Expensive and time consuming underground "cut and try" testing can be substantially reduced or eliminated by using the program to determine the range of cutting parameters that produces a minimum relative dust value. Those parameters which have the greatest effect on dust can be easily identified and given priority on any underground equipment changes to reduce dust generation.

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APPENDIX A.-PROGRAM LISTING

```
10 DIM NAM$(60), IV(60), PC(10), F$(1)
20 PRINT TAB(30);"CUTTING SYSTEM MODEL"
30 PRINT TAB(27)"LONGWALL SHEARER VERSION 2.0"
40 PRINT:PRINT TAB(20);"by Wallace W. Roepke and Bruce D. Hanson"
50 PRINT TAB(17);"US Department of the Interior, Bureau of Mines"
60 PRINT"     For technical assistance contact the authors at the Twin
     Cities"
70 PRINT"     Research Center, 5629 Minnehaha Avenue So., Minneapolis,
     MN 55417"
80 PRINT TAB(20);"or phone(612) 725-4780 or 725-4782"
90 PRINT:PRINT"     THIS PROGRAM CALCULATES RELATIVE RESPIRABLE DUST
     GENERATED BY A ROTARY DRUM"
100 PRINT"SHEARER BASED ON DRUM DIMENSIONS, SEAM PARAMETERS, AND
     OPERATING CONDITIONS."
110 PRINT"SECONDARY DUST, THAT IS, DUST GENERATED BY THE GRINDING
     ACTION OF THE DRUM AND"
120 PRINT"FALLING COAL IS INCLUDED IN THE CALCULATIONS. RELATIVE
     EFFECTS DUE TO CHANGES IN"
130 PRINT"THE SUPPRESSION AND/OR COLLECTION SYSTEMS ARE INCORPORATED.
     THE PROGRAM ALSO"
140 PRINT"CALCULATES CUTTING FORCES AND EVALUATES AN OPERATOR'S BIT
     COSTS, POWER COSTS,"
150 PRINT"AND PRODUCTION FOR EITHER NEW OR WORN BITS. THE USER MUST
     PROVIDE SITE SPECIFIC"
160 PRINT"MIDDLEMAN PARAMETERS. THE  USER CAN MODIFY ALL OF THE DRUM
     DIMENSIONS AND"
170 PRINT"OPERATING CONDITIONS EITHER COLLECTIVELY OR INDIVIDUALLY TO
     DETERMINE THE"
180 PRINT"RELATIVE CHANGES DUE TO INTERACTIVE EFFECTS ON DUST
     GENERATION, CUTTING FORCES,"
190 PRINT"BIT AND POWER COSTS, AND PRODUCTION FOR THEIR GIVEN SEAM
     CONDITIONS."
200 PRINT:PRINT".....HIT RETURN TO CONTINUE.....";:INPUT A$
205 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT TAB(30)"DISCLAIMER OF
     LIABILITY"
210 PRINT:PRINT:PRINT:PRINT"     The Bureau of Mines expressly declares
     that there are no warranties"
220 PRINT"express or implied which apply to the software contained
     herein. By acceptance"
230 PRINT"and use of said software, which is conveyed to the user
     without consideration"
240 PRINT"by the Bureau of Mines, the user hereof expressly waives any
     and all claims for"
250 PRINT"damage and/or suits for or by reason of personal injury, or
     property damage,"
260 PRINT"including special, consequential or similar damages arising
     out of or in any"
270 PRINT"way connected with the use of the software contained herein."
280 C1=LOG(10) :PI=3.1415926# :F$(0)="SCRN:" :F$(1)="LPT1:"
```

```
290 DEF FN DP(Z)=R+A*COS(Z)-SQR(R*R-A*A*SIN(Z)^2)
300 PRINT:PRINT:INPUT;"           ENTER DATA FILE NAME ";FI$:PRINT
310 OPEN "I", #1, FI$
320 FOR I=1 TO 60 :INPUT #1, NAM$(I), IV(I) :NEXT I
330 CLOSE:PRINT
340 GOTO 1980
350 LT$="NOT"
360 VL=SQR((PI*IV(2)*IV(8)/360)^2+IV(5)^2)
370 AN=ATN(PI*IV(2)*IV(8)/360/IV(5))*(180/PI)
380 VO=((IV(1)^2-IV(3)^2)*IV(4)*PI/4-VL*IV(7)*IV(6)*IV(11))*.66
390 CM=VO/IV(18)/3456*IV(13)
400 IF MA=0 THEN CF=CM
410 IF CF=>CM THEN LT$="VOLUME"
420 AD=CF/IV(1)/IV(4)*144
430 DC=AD*12/IV(11)/IV(13)
440 F2=VL*SIN(AN*PI/180)/IV(5):F3=IV(26)/IV(27)
450 F1=INT(VL*SIN(AN*PI/180)/IV(26))
460 IF F2 < F3 THEN F1=INT(IV(5)/IV(27))
470 IF IV(25) <= F1 THEN 490
480 GOTO 530
490 IF OB=0 THEN 590
500 OS=DC*SF
510 F=CINT(IV(5)/OS)
520 IF F < F1 THEN 580
530 PRINT:PRINT TAB(9)" THE SHEARER CAN'T EXCEED";F1;"BITS PER VANE FOR
     THE DRUM AND BIT"
540 PRINT TAB(9)" BLOCK DIMENSIONS BEING USED. THE AVAILABLE CUTTER
     TORQUE OR THE S/D"
550 PRINT TAB(9)" RATIO MUST BE INCREASED OR THE BIT BLOCK SIZE MUST BE
     CHANGED."
560 IV(25)=F1
570 GOTO 590
580 IV(25)=F
590 K=36:GOSUB 2730:MN=MF
600 K=49:GOSUB 2730
610 R=IV(1)/2
620 OS=IV(5)/IV(25)
630 DX=OS*TAN((90-IV(20)/2)*PI/180)
640 A=AD*12/IV(13)/IV(11)
650 A$="_ _ _ _ _ _ _ _ C_H_E_C_K_I_N_G_ _A_D_V_A_N_C_E_ _R_A_T_E_
     _O_F_ ##.##_ _F_E_E_T_ _P_E_R_ _M_I_N_U_T_E"
660 PRINT:PRINT USING A$;AD
670  REM
680  REM  VANE BITS - LEAD DRUM
690  REM
700 MT=IV(21):MB=IV(22):CH=IV(1):NB=IV(11)*IV(25)
710 P2=ATN(A/2/SQR(R*R-A*A/4))+PI/2
720 P3=-P2:GOSUB 2980
730 NV=MN*NF:CV=MF*FC:DV=D:LVC=CV:LVN=NV
740  REM
750  REM    GAGE BITS - LEAD DRUM
760  REM
770 A=12*AD/IV(13)/IV(28)*IV(12)
780 OS=(IV(4)-IV(5))/(IV(12)-1)
```

```
790 DX=OS*TAN((90-IV(20)/2)*PI/180)
800 P2=ATN(A/2/SQR(R*R-A*A/4))+PI/2
810 P3=-P2:NB=IV(28):GOSUB 2980
820 NG=MN*NF:CG=MF*FC:DG=D:LGC=CG:LGN=NG
830 RH=NV+NG:LA=RH
840 IF IV(9)<RH THEN 1110
850 AC=IV(1)/2*(CG+CV)/12:LS=AC
860 IF IV(10)<AC THEN 1150
870  REM
880  REM      GAGE BITS - TRAILING DRUM
890  REM
900 CH=IV(24)-IV(1)
910 IF CH<.01 THEN 1160
920 XY=MT:MT=IV(24)-MB:MB=IV(24)-XY
930 X=(IV(1)-2*CH)/IV(1):P1=ATN(X/SQR(1-X*X))
940 P2=ATN(A/2/SQR(R*R-A*A/4))+PI/2
950 P3=P1:GOSUB 2980
960 NG=NF*MN:CG=FC*MF:DG=DG+D
970  REM
980  REM   VANE BITS - TRAILING DRUM
990  REM
1000 OS=IV(5)/IV(25)
1010 DX=OS*TAN((90-IV(20)/2)*PI/180)
1020 A=AD*12/IV(13)/IV(11)
1030 NB=IV(11)*IV(25)
1040 X=(IV(1)-2*CH)/IV(1):P1=ATN(X/SQR(1-X*X))
1050 P2=ATN(A/2/SQR(R*R-A*A/4))+PI/2
1060 P3=P1:GOSUB 2980
1070 XY=MT:MT=IV(24)-MB:MB=IV(24)-XY
1080 NV=MN*NF:CV=MF*FC:DV=DV+D
1090 RH=NV+NG
1100 IF IV(9)>RH THEN 1130
1110 LT$="ADVANCE"
1120 AD=.95*AD:GOTO 430
1130 AC=IV(1)/2*(CG+CV)/12
1140 IF IV(10)>AC THEN 1160
1150 LT$="CUTTER":GOTO 1120
1160 DC=AD*12/IV(11)/IV(13)
1170 GD=DC/IV(28)*IV(12)*IV(11)
1180 CF=AD*IV(1)*IV(4)/144
1190 TP=CF*IV(19)/2000*IV(24)/IV(1)
1200 OS=IV(5)/IV(25)
1210 K=0
1220 OPEN F$(K) FOR OUTPUT AS #1
1230 PRINT #1," ", :PRINT #1," "
1240 PRINT #1,"THE DRUM ADVANCE IS ";LT$;" LIMITED";
1250 PRINT #1, TAB(40)"THE BITS ARE ";WC;" PERCENT WORN"
1260 PRINT#1," "
1270 A$="_M_A_X_._ _C_U_T_ _D_E_P_T_H_,_ _V_A_N_E_ _B_I_T_
     _(_I_N_)####.##"
1280 PRINT #1, USING A$;DC;
1290 A$="_M_A_X_._ _C_U_T_ _D_E_P_T_H_,_ _G_A_G_E_ _B_I_T_
     _(_I_N_)####.##"
1300 PRINT #1, TAB(40);:PRINT #1, USING A$;GD
```

```
1310 A$="_L_I_N_E_ _B_I_T_ _S_P_A_C_I_N_G_ _(_I_N_)_ _ _ _ _ _ _ _ _
     ####.##"
1320 PRINT #1, USING A$;OS;
1330 A$="_N_U_M_B_E_R_ _O_F_ _G_A_G_E_ _L_I_N_E_S_ _ _ _ _ _ _ _ _ _
     ####.##"
1340 PRINT #1, TAB(40);:PRINT #1, USING A$;IV(12)
1350 A$="_B_I_T_S_ _P_E_R_ _V_A_N_E_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
     ####.##"
1360 PRINT #1, USING A$;IV(25);
1370 PO=IV(28)/IV(12)
1380 A$="_N_U_M_B_E_R_ _O_F_ _G_A_G_E_ _B_I_T_S_ _P_E_R_ _L_I_N_E_
     ####.##"
1390 PRINT #1, TAB(40);:PRINT #1, USING A$;PO
1400 A$="_B_I_T_ _S_P_A_C_E_ _T_O_ _D_E_P_T_H_ _R_A_T_I_O_ _ _ _ _
     ####.##"
1410 PRINT #1, USING A$;OS/DC
1420 PRINT #1," "
1430 A$="_A_V_A_I_L_A_B_L_E_ _A_D_V_A_N_C_I_N_G_ _T_H_R_U_S_T_ _ _
     #######"
1440 PRINT #1, USING A$;IV(9);
1450 A$="_A_V_A_I_L_A_B_L_E_ _C_U_T_T_E_R_ _T_O_R_Q_U_E_ _ _ _ _ _
     #######"
1460 PRINT #1, TAB(40);:PRINT #1, USING A$;IV(10)
1470 A$="_L_E_A_D_ _D_R_U_M_ _A_D_V_A_N_C_I_N_G_ _T_H_R_U_S_T_ _ _
     #######"
1480 PRINT #1, USING A$;LA;
1490 A$="_L_E_A_D_ _D_R_U_M_ _C_U_T_T_E_R_ _T_O_R_Q_U_E_ _ _ _ _ _
     #######"
1500 PRINT #1, TAB(40);:PRINT #1, USING A$;LS
1510 A$="_T_R_A_I_L_I_N_G_ _D_R_U_M_ _A_D_V_._ _T_H_R_U_S_T_ _ _ _
     #######"
1520 IF IV(1)=IV(24) THEN 1560
1530 PRINT #1, USING A$;RH;
1540 A$="_T_R_A_I_L_I_N_G_ _D_R_U_M_ _C_U_T_T_E_R_ _T_O_R_Q_U_E_ _
     #######"
1550 PRINT #1, TAB(40);:PRINT #1, USING A$;AC
1560 PRINT #1," "
1570 A$="_A_D_V_A_N_C_E_ _(_F_T_/_M_I_N_)_ _ _ _ _ _ _ _ _ _ _ _ _ _
     ####.##"
1580 PRINT #1, USING A$;AD;
1590 PS=TP*4.8*IV(31)
1600 A$="_T_O_N_S_ _P_E_R_ _S_H_I_F_T_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
     ####.##"
1610 PRINT #1, TAB(40);:PRINT #1, USING A$;PS
1620 PRINT #1," "
1630 GOSUB 3510
1640 A$="_C_O_S_T_/_T_O_N_ _-_ _B_I_T_S_ _A_N_D_ _P_O_W_E_R_ _ _ _
     ####.##"
1650 PRINT #1, USING A$;CT;
1660 A$="_C_O_S_T_/_S_H_I_F_T_ _-_ _B_I_T_S_ _A_N_D_ _P_O_W_E_R_ _
     ####.##"
1670 PRINT #1, TAB(40);:PRINT #1, USING A$;CT*PS
1680 PRINT #1," "
1690 DU=DV+DG
```

```
1700 VC=100*DV/DU:GC=100-VC:DU=DU*IV(17)*(100-IV(30))/1000
1710 DU=DU*PI*IV(1)/12:DM=DU*IV(13)/7.7E+08:DT=DM/TP
1720 DS=35.3145*DM/IV(29):DS=DS*IV(31)/100
1730 A$="_V_A_N_E_ _C_O_N_T_R_I_B_U_T_I_O_N_ _(_P_C_T_)_ _ _ _ _ _
     ####.##"
1740 PRINT #1, USING A$;VC;
1750 A$="_G_A_G_E_ _C_O_N_T_R_I_B_U_T_I_O_N_ _(_P_C_T_)_ _ _ _ _ _
     ####.##"
1760 PRINT #1, TAB(40);:PRINT #1, USING A$;GC:PRINT #1," "
1770 IF CF>CM THEN 1820
1780 PRINT #1,"":PRINT#1,TAB(3);"********************************************
     ************************************** "
1790 A$="*_ _F_U_L_L_ _S_H_I_F_T_ _R_E_L_A_T_I_V_E_ _D_U_S_T_ _-_
     #######.##_ _P_E_R_ _T_O_N#######.##_ _P_E_R_ _C_U_._ _M_._ _*"
1800 PRINT#1,TAB(3);: PRINT#1,USING A$;DT;DS
1810 PRINT#1,TAB(3);"*********************************************************
     ************************":GOTO 1900
1820 PRINT #1," ":PRINT #1,TAB(18);"****************************************
     *******"
1830 PRINT #1, TAB(18)"* DUST GENERATION IS EXCESSIVE          *"
1840 PRINT#1,TAB(18); "************************************************"
1850 PRINT #1, TAB(18)"* THE FREE VOLUME OF THE DRUM HAS BEEN  *"
1860 PRINT #1, TAB(18)"* EXCEEDED, EXCESSIVE RESPIRABLE DUST   *"
1870 PRINT #1, TAB(18)"* IS BEING CREATED BY RECIRCULATION AND *"
1880 PRINT #1, TAB(18)"* CRUSHING OF THE CUT COAL              *"
1890 PRINT #1, TAB(18)"*****************************************"
1900 PRINT#1," " :CLOSE
1910 IF K=1 THEN 1980
1920 PRINT TAB(21)"DO YOU WISH A HARD COPY (Y/N) ";
1930 INPUT A$
1940 IF A$="N" THEN 1980
1950 IF A$="Y" THEN 1970
1960 GOTO 1920
1970 K=1:GOTO 1220
1980 OB=0:MA=0
1990 PRINT:PRINT:PRINT"##################################  MAIN MENU
     ##################################"
2000 PRINT:PRINT"1 - RECALCULATE RELATIVE DUST VALUE";:PRINT TAB(40)"2
     - MODIFY SYSTEM PARAMETERS"
2010 PRINT"3 - SPECIFY ADVANCE RATE";:PRINT TAB(40)"4 - SPECIFY
     SPACE/DEPTH RATIO"
2020 PRINT"5 - CHANGE WEAR CONDITION";:PRINT TAB(40)"6 - DATA FILE
     UTILITY"
2030 PRINT "7 - HELP INDEX";:PRINT TAB(40)"8 - TERMINATE PROGRAM"
2040 PRINT:PRINT TAB(9)"ENTER THE NUMBER FOR THE ACTION YOU WISH TO DO
     NEXT ";:INPUT WT
2050 WT=WT+1 :ON WT GOTO 2260, 350, 2100, 2070, 2250, 2240, 2080, 2060,
     2260
2060 GOSUB 3600 :GOTO 1990
2070 GOSUB 2310 :GOTO 1990
2080 GOSUB 3310 :GOTO 1990
2090 GOSUB 3510 :GOTO 1990
2100 PRINT:PRINT:PRINT"#######################  PARAMETER MODIFICATION
     MENU  #######################"
```

```
2110 PRINT:PRINT "1 - MACHINE PARAMETERS"; :PRINT TAB(40)"2 - SEAM
     PARAMETERS"
2120 PRINT "3 - OPERATOR CONTROLLABLE PARAMETERS"; :PRINT TAB(40)"4 -
     BIT NORMAL FORCE PARAMETERS"
2130 PRINT "5 - BIT CUTTING FORCE PARAMETERS"; :PRINT TAB(40)"6 - HELP
     INDEX"
2140 PRINT "7 - RETURN TO MAIN MENU"
2150 PRINT:PRINT TAB(9)"ENTER THE NUMBER FOR THE PARAMETER GROUP YOU
     WISH TO MODIFY "; :INPUT MT
2160 ON MT GOTO 2170, 2180, 2190, 2200, 2210, 2220, 2230
2170 N1=1:N2=13:GOSUB 2540: GOTO 2100
2180 N1=14:N2=24:GOSUB 2540: GOTO 2100
2190 N1=25:N2=34:GOSUB 2540: GOTO 2100
2200 N1=35:N2=47:GOSUB 2540: GOTO 2100
2210 N1=48:N2=60:GOSUB 2540: GOTO 2100
2220 GOSUB 4200: GOTO 2100
2230 GOTO 1990
2240 PRINT:PRINT TAB(18)"ENTER WEAR CONDITION (%) - ";: INPUT WC:
     GOTO 1990
2250 GOSUB 2470: GOTO 1990
2260 PRINT:PRINT TAB(9)"ARE YOU SURE YOU WISH TO TERMINATE THE
     PROGRAM (Y/N) ";: INPUT A$
2270 IF A$="Y" THEN 2300
2280 IF A$="N" THEN 1990
2290 GOTO 2260
2300 END
2310 PRINT:PRINT TAB(9)"YOU MAY CHANGE THE ADVANCE IN UNITS OF FEET
     PER"
2320 PRINT TAB(9)"MINUTE, OR TONS PER SHIFT"
2330 PRINT:PRINT TAB(9)"ENTER NEW VALUE IF YOU WISH TO CHANGE FEET PER
     MINUTE,"
2340 PRINT TAB(9),"OTHERWISE ENTER ZERO";
2350 INPUT " (0) - ";AD
2360 MA=1
2370 IF AD=0 THEN 2400
2380 CF=IV(1)*IV(4)*AD/144
2390 RETURN
2400 PRINT:PRINT TAB(9)"ENTER NEW VALUE IF YOU WISH TO CHANGE TONS PER
     SHIFT,"
2410 PRINT TAB(9),"OTHERWISE ENTER ZERO";
2420 INPUT " (0) - ";TP
2430 TP=TP/4.8/IV(31)*IV(1)/IV(24)
2440 IF TP=0 THEN 2310
2450 CF=2000*TP/IV(19)
2460 RETURN
2470 PRINT:PRINT TAB(18)"SUGGESTED SPACE TO DEPTH RATIOS"
2480 PRINT:PRINT TAB(23)"A) CLEAN COAL ..............   2"
2490 PRINT TAB(23)"B) SEAM WITH ROCK BAND......   1.3"
2500 PRINT TAB(23)"C) CUTTING ROCK TOP.........   1"
2510 PRINT:PRINT TAB(18)"PREVIOUS S/D RATIO REQUESTED WAS";SF;"."
2520 PRINT:PRINT TAB(18)"ENTER NEW SPACE/DEPTH RATIO - ";:INPUT SF
2530 OB=1:RETURN
2540 N=0:PRINT:PRINT
2550 FOR I=N1 TO N2
```

```
2560 X=35-LEN(NAM$(I))-INT(I/10)
2570 PRINT TAB(18)I;" - ";NAM$(I); SPC( X);IV(I)
2580 NEXT I
2590 PRINT:PRINT TAB(18)"ENTER THE NUMBER OF THE VARIABLE YOU WISH "
2600 PRINT TAB(18)"TO CHANGE, USE ZERO(0) TO TERMINATE ";: INPUT "- ";J
2610 IF J=0 THEN 2650
2620 N=N+1: PC(N)=J: PRINT TAB(18)"ENTER NEW ";NAM$(J);
2630 INPUT " - ";IV(J)
2640 GOTO 2590
2650 IF N=0 THEN RETURN
2660 PRINT:PRINT TAB(18)"DO YOU WISH A HARD COPY OF THESE
     CHANGES (Y/N)";: INPUT A$
2670 IF A$="Y" THEN 2700
2680 IF A$="N" THEN RETURN
2690 GOTO 2660
2700 OPEN F$(1) FOR OUTPUT AS #1
2710 FOR K=1 TO N: L=PC(K) :PRINT #1, TAB(9)"********* ";NAM$(L);
     " - ";IV(L) :NEXT K
2720 PRINT #1," " :PRINT #1," " :PRINT #1," " :PRINT #1," " :
     CLOSE:RETURN
2730 J=0
2740 FOR I=1 TO 3
2750 J=J+1 :K=K+3
2760 IF WC<=IV(K) THEN 2780
2770 NEXT I
2780 MF=IV(K+1)+WC*IV(K+2)
2790 RETURN
2800 SM=FN DP(P1)
2810 IF SM>DX THEN SM=DX
2820 IF F=1 THEN SM=SM*COS(P1)
2830 DL=FN DP(P2)
2840 IF DL>DX THEN DL=DX
2850 IF F=1 THEN DL=DL*COS(P2)
2860 SM=SM+DL :DL=(P2-P1)/10
2870 FOR I=2 TO 8 STEP 2
2880 X=FN DP(I*DL+P1)
2890 IF X>DX THEN X=DX
2900 IF F=1 THEN X=X*COS(I*DL+P1)
2910 SM=SM+2*X :NEXT I
2920 FOR I=1 TO 9 STEP 2
2930 X=FN DP(I*DL+P1)
2940 IF X>DX THEN X=DX
2950 IF F=1 THEN X=X*COS(I*DL+P1)
2960 SM=SM+4*X :NEXT I
2970 SM=SM/30 :RETURN
2980 NF=0:FC=0:D=0
2990 IF MT=MB OR MT=>CH THEN 3250
3000  REM
3010  REM    CALCULATE DUST & FORCES FOR TOP COAL
3020  REM
3030 X=(IV(1)-2*MT)/IV(1):P1=ATN(X/SQR(1-X*X))
3040 F=1:GOSUB 2800
3050 NF=(IV(35)*(SIN(P2)-SIN(P1))/(P2-P1)+IV(36)*SM)*(P2-P1)/PI/2*NB
3060 F=0:GOSUB 2800
```

```
3070 D=(IV(14)+SM*IV(15))*(P2-P1)/PI/2*NB
3080 FC=(IV(48)+SM*IV(49))*(P2-P1)/PI/2*NB
3090  REM
3100  REM    CALCULATE DUST & FORCES FOR MIDDLEMAN
3110  REM
3120 P2=P1:P1=P3
3130 IF MB=>CH THEN 3150
3140 X=(IV(1)-2*MB)/IV(1):P1=ATN(X/SQR(1-X*X))
3150 F=1:GOSUB 2800
3160 NF=NF+(IV(37)*(SIN(P2)-SIN(P1))/(P2-P1)+ IV(38)*SM)*(P2-P1)
     /PI/2*NB
3170 F=0:GOSUB 2800
3180 FC=FC+(IV(50)+IV(51)*SM)*(P2-P1)/PI/2*NB
3190 D=D+((IV(14)+SM*IV(15))*(P2-P1)/PI/2*NB)*(5^(IV(23)*.01))*2
3200 IF MB=>CH THEN RETURN
3210  REM
3220  REM CALCULATE BOTTOM COAL DUST & FORCES
3230  REM
3240 P2=P1
3250 P1=P3:F=1:GOSUB 2800
3260 NF=NF+(IV(35)*(SIN(P2)-SIN(P1))/(P2-P1)+IV(36)*SM)*(P2-P1)/PI/2*NB
3270 F=0:GOSUB 2800
3280 D=D+(IV(14)+SM*IV(15))*(P2-P1)/PI/2*NB
3290 FC=FC+(IV(48)+SM*IV(49))*(P2-P1)/PI/2*NB
3300 RETURN
3310 PRINT:PRINT:PRINT"##############################  DATA FILE
     UTILITY #############################"
3320 PRINT:PRINT"1 - SAVE CURRENT DATA FILE";: PRINT TAB(40)"2 - PRINT
     CURRENT DATA FILE"
3330 PRINT"3 - READ NEW DATA FILE";: PRINT TAB(40)"4 - RETURN TO MAIN
     MENU"
3340 PRINT:PRINT TAB(9)"ENTER THE NUMBER FOR THE ACTION YOU WISH TO DO
     NEXT ";:INPUT WT
3350 ON WT GOTO 3360,3440,3400 ,4190
3360 PRINT:INPUT;"         ENTER SAVE DATA FILE NAME ";FI$:PRINT
3370 OPEN "O", #2, FI$
3380 FOR I=1 TO 60 :PRINT #2, NAM$(I);",";IV(I) :NEXT I:CLOSE 2
3390 GOTO 3310
3400 PRINT:PRINT TAB(9)"ENTER NEW DATA FILE NAME ";:INPUT FI$
3410 OPEN "I", #1, FI$
3420 FOR I=1 TO 60 :INPUT #1, NAM$(I), IV(I) :NEXT I  :CLOSE
3430 GOTO 3310
3440 OPEN "O", #1, "LPT1:"
3450 A$="#####_ _ _ \                                       \"
3460 FOR I=1 TO 60 :PRINT #1,USING A$; I, NAM$(I);
3470 PRINT #1,IV(I):NEXT I
3480 CLOSE 1
3490 GOTO 3310
3500 RETURN
3510 TH=LA:IF IV(24)>IV(1) THEN TH=TH+RH
3520 HR=LS:IF IV(24)>IV(1) THEN HR=HR+AC
3530 KW=.746*(AD*TH/33000!+IV(13)*HR/5260)
3540 KH=KW*IV(31)*8/100
3550 BL=IV(34)
```

```
3560 IF IV(22)-IV(21)=0 THEN 3590
3570 IF IV(22)-IV(21)>0 THEN 3580
3580 BL=IV(34)/SQR(IV(22)-IV(21))/SQR(4.3^(IV(23)*.01)-.02*IV(23))
3590 CT=IV(32)/BL+KH*IV(33)/PS :RETURN
3600 REM HELP MENU3
3610 PRINT:PRINT:PRINT"##########################  HELP INDEX FOR MAIN
     MENU  ########################"
3620 PRINT:PRINT"1 - RECALCULATE RELATIVE DUST VALUE";: PRINT TAB(40)
     "2 - MODIFY SYSTEM PARAMETERS"
3630 PRINT"3 - SPECIFY ADVANCE RATE";: PRINT TAB(40)"4 - SPECIFY BIT
     SPACING"
3640 PRINT"5 - CHANGE WEAR CONDITION";: PRINT TAB(40)"6 - SAVE DATA
     FILE"
3650 PRINT "7 - RETURN TO MAIN MENU"
3660 PRINT:PRINT TAB(9)"ENTER THE NUMBER FOR THE ITEM FOR WHICH YOU
     DESIRE HELP ";:INPUT HT
3670 ON HT GOTO 3680, 3800, 3870, 3980, 4070, 4140, 4190
3680 PRINT:PRINT:PRINT"****************** MENU 1 - RECALCULATE
     RELATIVE DUST VALUE ******************"
3690 PRINT"     THIS MENU ITEM WILL CAUSE THE PROGRAM TO CALCULATE THE
     RELATIVE DUST VALUE"
3700 PRINT"BASED ON THE CURRENT PARAMETER VALUES AND SPECIFIED ADVANCE
     RATE. THE USER MAY"
3710 PRINT"PRINT A HARD COPY OF THE SUMMARY REPORT WHEN THE
     CALCULATIONS ARE COMPLETE. THE"
3720 PRINT"ADVANCE RATE WHICH IS CURRENTLY BEING EVALUATED WILL BE
     SHOWN ON THE SCREEN."
3730 PRINT"IF THE AVAILABLE HORSEPOWER IS UNABLE TO ADVANCE THE MACHINE
     AT THE SPECIFIED"
3740 PRINT"RATE THE PROGRAM WILL DECREASE THE ADVANCE RATE UNTIL THE
     REQUIRED HORSEPOWER"
3750 PRINT"IS LESS THAN THE AVAILABLE. THE DEFAULT MODE WILL CALCULATE
     RELATIVE DUST"
3760 PRINT"BASED ON THE MAXIMUM VOLUME OF CUT COAL THE DRUM CAN HOLD.
     THE PROGRAM WILL"
3770 PRINT"REVERT TO THE DEFAULT MODE AFTER A RUN SO ITEM 3 WILL
     NORMALLY BE USED EACH RUN."
3780 PRINT "***********************************************************
     **********************"
3790 GOTO 3610
3800 PRINT:PRINT:PRINT"****************** MENU ITEM 2 - MODIFY SYSTEM
     PARAMETERS ********************"
3810 PRINT"     THE USER CAN CHANGE ANY OF THE 60 VARIABLES USED BY THE
     PROGRAM TO DESCRIBE"
3820 PRINT"THE CUTTING SYSTEM  THE VARIABLE LIST IS SUBDIVIDED INTO
     FIVE GROUPS FOR EASIER"
3830 PRINT"HANDLING . WHEN ALL THE CHANGES HAVE BEEN MADE THE USER MAY
     OBTAIN A HARD COPY"
3840 PRINT"OF THE CHANGES."
3850 PRINT "***********************************************************
     **********************"
3860 GOTO 3610
3870 PRINT:PRINT:PRINT"********************* MENU ITEM 3 - SPECIFY
     ADVANCE RATE ********************"
```

```
3880 PRINT "     THIS OPTION ALLOWS THE USER TO SPECIFY THE ADVANCE
     RATE TO BE USED IN THE"
3890 PRINT "CALCULATIONS. THE ADVANCE RATE CAN BE ENTERED EITHER IN
     FEET PER MINUTE OR IN"
3900 PRINT "TONS PER SHIFT. TO ENTER THE ADVANCE RATE IN TONS PER
     SHIFT, SIMPLY ENTER ZERO"
3910 PRINT "(0) FOR THE FEET PER MINUTE PROMPT. THE PROGRAM WILL THEN
     ASK FOR THE ADVANCE"
3920 PRINT "RATE IN TONS PER SHIFT. IT IS IMPORTANT TO REMEMBER THAT
     THE PROGRAM WILL USE"
3930 PRINT "THIS SPECIFIED ADVANCE RATE FOR THE NEXT DUST CALCULATION
     ONLY. IT THEN REVERTS"
3940 PRINT "TO THE DEFAULT VALUE WHICH IS CALCULATED FROM THE MAXIMUM
     VOLUME THE DRUM CAN"
3950 PRINT "HOLD."
3960 PRINT "**********************************************************
     **********************"
3970 GOTO 3610
3980 PRINT:PRINT:PRINT"******************** MENU ITEM 4 - SPECIFY
     SPACE/DEPTH RATIO *********************"
3990 PRINT"     SELECTING THIS MENU ITEM WILL CAUSE THE PROGRAM TO
     CALCULATE THE NUMBER OF"
4000 PRINT"VANE BITS (DATA ELEMENT 26) BASED ON THE CALCULATED DEPTH
     AND SPECIFIED S/D"
4010 PRINT"RATIO. IF FOR ANY REASON THE SHEARER CAN NOT ADVANCE AT THE
     SPECIFIED RATE THE"
4020 PRINT"NUMBER OF VANE BITS WILL BE RECALCULATED ON EACH ITERATION.
     THE PROGRAM WILL USE"
4030 PRINT"THIS MODE ONLY FOR THE NEXT DUST CALCULATION, AFTER WHICH IT
     WILL REVERT TO THE"
4040 PRINT"NUMBER OF VANE BITS SPECIFIED IN DATA ELEMENT 26."
4050 PRINT "**********************************************************
     **********************"
4060 GOTO 3610
4070 PRINT:PRINT:PRINT"********************* MENU ITEM 5 - CHANGE WEAR
     CONDITION **********************"
4080 PRINT"     THE USER CAN CHANGE THE WEAR CONDITION OF BITS THROUGH
     THIS MENU ITEM. THE"
4090 PRINT"WEAR CONDITION IS EXPRESSED IN A PERCENTAGE, ZERO (0) BEING
     A NEW BIT, AND 100"
4100 PRINT"REPRESENTING A TOTALLY WORN BIT. THE WEAR CONDITION IS USED
     TO DETERMINE A FORCE"
4110 PRINT"MULTIPLIER FOR THE BITS."
4120 PRINT "**********************************************************
     **********************"
4130 GOTO 3610
4140 PRINT:PRINT:PRINT"************************ MENU ITEM 6 - DATA FILE
     UTILITY **********************"
4150 PRINT"    THIS OPTION ALLOWS THE USER TO SAVE THE CURRENT DATA
     FILE, READ A NEW DATA,"
4160 PRINT"OR OBTAIN A PRINTER LISTING OF DATA FILE VALUES"
4170 PRINT "**********************************************************
     **********************"
4180 GOTO 3610
```

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4190 RETURN
4200 PRINT:PRINT:PRINT"################  HELP INDEX FOR PARAMETER
     MODIFICATION MENU  ###############"
4210 PRINT:PRINT "1 - MACHINE PARAMETERS";: PRINT TAB(40)"2 - SEAM
     PARAMETERS"
4220 PRINT "3 - OPERATOR CONTROLLABLE PARAMETERS";: PRINT TAB(40)"4 -
     BIT NORMAL FORCE PARAMETERS"
4230 PRINT "5 - CUTTING FORCE PARAMETERS";: PRINT TAB(40)"6 - RETURN TO
     PARAMETER MODIFICATION MENU"
4240 PRINT:PRINT TAB(9)"ENTER THE NUMBER OF THE MENU ITEM FOR WHICH YOU
     REQUIRE HELP ";:INPUT HT
4250 ON HT GOTO 4260, 4330, 4420, 4480, 4480, 4540
4260 PRINT:PRINT:PRINT"***************** MENU ITEM 1 - MODIFY MACHINE
     PARAMETERS *********************"
4270 PRINT"    THE USER CAN CHANGE ANY OF THE 13 VARIABLES WHICH
     DESCRIBE THE SHEARER DRUM."
4280 PRINT"THE PROGRAM HAS NO INTERNAL ERROR CHECKING ROUTINES TO
     INSURE THAT THE DRUM"
4290 PRINT"DIMENSIONS ARE CONSISTENT WITH EACH OTHER ( E.G., THE WEB
     WIDTH IS GREATER THAN"
4300 PRINT"THE VANE WIDTH ETC.)."
4310 PRINT "**************************************************************
     **********************"
4320 GOTO 4200
4330 PRINT:PRINT:PRINT"********************* MENU ITEM 2 - MODIFY SEAM
     PARAMETERS *********************"
4340 PRINT"    THE USER CAN CHANGE ANY OF 11 SEAM AND/OR COAL PROPERTY
     VARIABLES. THE ROCK"
4350 PRINT"BAND VALUES (TOP AND BOTTOM) ARE MEASURED FROM THE TOP OF
     THE MINING HORIZON."
4360 PRINT"TWO ASPECTS OF PROGRAM FLOW ARE CONTROLLED BY VARIABLES IN
     THIS MENU. FIRST"
4370 PRINT"SETTING THE ROCK BAND TOP EQUAL TO THE ROCK BOTTOM WILL
     CAUSE THE PROGRAM TO"
4380 PRINT"CONSIDER CUTTING ONLY COAL. SECOND, IF THE SEAM HEIGHT IS
     EQUAL TO THE DRUM"
4390 PRINT"DIAMETER THE PROGRAM WILL BASE THE CALCULATIONS ON ONE DRUM
     ONLY."
4400 PRINT "**************************************************************
     **********************"
4410 GOTO 4200
4420 PRINT:PRINT:PRINT"************ MENU ITEM 3 - MODIFY
     OPERATOR-CONTROLLABLE PARAMETERS ************"
4430 PRINT"    THIS MENU ALLOWS THE USER TO CHANGE 10 'CONTROLLABLE'
     PARAMETERS SUCH AS"
4440 PRINT"AIR FLOW, PRODUCTION TIME PER SHIFT, NUMBER OF BITS, BIT
     LIFE, COST OF BITS,"
4450 PRINT"COST OF POWER, AND DUST SUPPRESSION ETC."
4460 PRINT "**************************************************************
     **********************"
4470 GOTO 4200
4480 PRINT:PRINT:PRINT"****************************** MENU ITEMS 4
     AND 5 ******************************"
4490 PRINT"    THE USER CAN CHANGE ANY OF 26 FORCE AND WEAR
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     CHARACTERISTICS OF THE BITS"
4500 PRINT"BEING USED IN THE ANALYSIS. THE VALUES FOR FORCE AND WEAR
     PARAMETERS MUST BE"
4510 PRINT"OBTAINED FROM IN SITU FORCE MEASUREMENTS AND FROM LAB WEAR
     TESTS."
4520 PRINT "**********************************************************
     **********************"
4530 GOTO 4200
4540 RETURN
```

APPENDIX B.–PARAMETER DEFINITION

Element	Name	Dimensions	Description
		MACHINE PARAMETERS	
1	Drum diameter	in	Bit tip to bit tip diameter.
2	Top vane diameter	in	Diameter as measured to top of the vanes.
3	Inner drum diameter	in	Diameter of inner drum.
4	Web width	in	Width of cut removed by drum.
5	Vane width	in	Width of vane section of drum.
6	Vane thickness	in	Thickness of vane measured perpendicular to vane.
7	Vane height	in	Height of vanes, inner drum diameter plus twice vane height should equal top vane diameter.
8	Drum vane wrap	deg	Wrap angle of drum.
9	Available advancing thrust	lb	Thrust available to advance shearer drum unto coal.
10	Available cutter torque	ft•lb	Cutterhead torque available to turn shearer drum.
11	Number of starts	NAp	Number of starts on the drum.
12	Number of gauge lines	NAp	Number of gauge lines on drum end ring.
13	Drum revolutions	rpm	Drum speed.
		SEAM PARAMETERS	
14	1st dust parameter	NAp	Intercept of linear dust versus cut depth equation.
15	2d dust parameter	NAp	Slope of linear dust versus cut depth equation.
16	Compressive strength[1]	lb/in^2	Compressive strength.
17	Grindability index	NAp	Hardgrove grindability index.
18	Swell factor	NAp	Ratio of mined volume to in situ volume.
19	Density	lb/ft^3	Density of run-of-mill product.
20	Breakout angle	deg	Measure of bit interaction, included angle of trench left by bit.
21	Rock band top	in	Distance from top of seam to top of rock band.
22	Rock band bottom	in	Distance from top of seam to bottom of the rock band; if set equal to rock band top program assumes there is no rock band.
23	Percent silica in rock band	pct	Percent silica in the rock band.
24	Mining height	in	Height of coal and rock being removed, if set equal to drum diameter the program will assume a single drum is being analyzed.
		OPERATOR CONTROLLABLE PARAMETERS	
25	Bits per vane	NAp	Number of bits on each vane.
26	Bit block length	in	Length of vane bit blocks.
27	Bit block width	in	Width of vane bit blocks.
28	Number of gauge bits	NAp	Total gauge bits on end of drum.
29	Airflow	cfm	Av airflow at middle of face.
30	Dust suppression	pct	Percent reduction in total dust value due to secondary water suppression system.
31	Production time per shift	pct	Percent of shift spent cutting coal, based on an 8-hr shift.
32	Cost per bit	NAp	Cost of bit installed on drum.
33	Cost per kilowatt-hour	NAp	Cost per kilowatt-hour at face.
34	Bit life	st	Av bit life.
		BIT NORMAL FORCE PARAMETERS*	
35	Normal force intercept	NAp	Intercept for normal force versus cut depth equation, cutting in coal.
36	Normal force slope	NAp	Slope for normal force versus cut depth equation, cutting in coal.
37	Rock band normal force intercept	NAp	Intercept for the normal force versus cut depth equation, cutting in rock.
38	Rock band normal force slope	NAp	Slope for the normal force versus cut depth equation, cutting in rock.
39	1st stage end point	pct	End of the first straight line segment of the wear function.
40	1st stage intercept	NAp	Intercept of the first straight line segment.
41	1st stage slope	NAp	Slope of the first straight line segment.
42	2d stage end point	pct	End of the second straight line segment of the wear function.
43	2d stage intercept	NAp	Intercept of the second straight line segment.
44	2d stage slope	NAp	Slope of the second straight line segment.
45	3d stage end point	pct	End of the third straight line segment of the wear function.
46	3d stage intercept	NAp	Intercept of the third straight line segment.
47	3d stage slope	NAp	Slope of the third straight line segment
		BIT CUTTING FORCE PARAMETERS*	
48	Cutting force intercept	NAp	Intercept for the cutting force versus cut depth equation, cutting in coal.
49	Cutting force slope	NAp	Slope for the cutting force versus cut depth equation, cutting in coal.
50	Rock band cutting force intercept	NAp	Intercept for the cutting force versus cut depth equation, cutting in rock.
51	Rock band cutting force slope	NAp	Slope for the cutting force versus cut depth equation, cutting in rock.
52	1st stage end point	pct	End of the first straight line segment of the wear function.
53	1st stage intercept	NAp	Intercept of the first straight line segment.
54	1st stage slope	NAp	Slope of the first straight line segment.
55	2d stage end point	pct	End of the second straight line segment of the wear function.
56	2d stage intercept	NAp	Intercept of the second straight line segment.
57	2d stage slope	NAp	Slope of the second straight line segment.
58	3d stage end point	pct	End of the third straight line segment of the wear function.
59	3d stage intercept	NAp	Intercept of the third straight line segment.
60	3d stage slope	NAp	Slope of the third straight line segment.

NAp Not applicable. [1]Not used in current version of program. *From laboratory and/or In-Seam Tester data.

APPENDIX C.–SAMPLE DATA

Element	Name	Value	Element	Name	Value
1	Drum diameter ... in	66	31	Production time per shift ... pct	24
2	Top vane diameter ... in	60	32	Cost per bit	5
3	Inner drum diameter ... in	34	33	Cost per kilowatt-hour	0.06
4	Web width ... in	38.5	34	Bit life ... st	130
5	Vane width ... in	34.5	35	Normal force intercept	60
6	Vane thickness ... in	2	36	Normal force slope	260
7	Vane height ... in	13	37	Rock band normal force intercept	156
8	Drum vane warp ... deg	220	38	Rock band normal force slope	436
9	Available advancing thrust ... lb	6,000	39	1st stage end point ... pct	25
10	Available cutter torque ... ft/lb	50,000	40	1st stage intercept	1
11	Number of starts	3	41	1st stage slope	0.12
12	Number of gauge lines	5	42	2d stage end point ... pct	50
13	Drum revolutions ... rpm	34	43	2d stage intercept	2
14	1st dust parameter	5.0×10^7	44	2d stage slope	0.08
15	2d dust parameter	2.5×10^7	45	3d stage end point ... pct	100
16	Compressive strength ... lb/in^2	3,061	46	3d stage intercept	6
17	Grindability index	46	47	3d stage slope	0
18	Swell factor	1.45	48	Cutting force intercept	50
19	Density ... lb/ft^3	115	49	Cutting force slope	250
20	Breakout angle ... deg	100	50	Rock band cutting force intercept	-68
21	Rock band top ... in	60	51	Rock band cutting force slope	592
22	Rock band bottom ... in	78	52	1st stage end point ... pct	25
23	Silica in rock band ... pct	75	53	1st stage intercept	1
24	Mining height ... in	96	54	1st stage slope	0.06
25	Bits per vane	7	55	2d stage end point ... pct	50
26	Bit block length ... in	4	56	2d stage intercept	1.5
27	Bit block width ... in	3	57	2d stage slope	0.04
28	Number of gauge bits	18	58	3d stage end point ... pct	100
29	Airflow ... cfm	27,000	59	3d stage intercept	2.5
30	Dust suppression ... pct	33	60	3d stage slope	0.02

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